Economic Load Dispatch of Power Plant in Electric Generation System Using Grey Wolf Optimization

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***Abstract*- In this paper work, we have applied the Grey Wolf Optimization (GWO) method to solve the Global Economic Load Dispatch Problem (ELDP) by considering with and without transmission losses. The GWO method imitates the superiority ranking and feeding mechanism of grey wolves in nature. For simulating the superiority ranking follows as alpha, beta, omega and delta. For feeding the prey grey wolves follows three steps, in the order of searching, encircling and attacking, are carry out to perform optimization. The intention of ELDP is to curtail the fuel cost for any viable load demand and at the same time to determine the optimal power generation. The potency of the GWO method has been examined on IEEE 30-bus test system with four different load demands by considering four different case studies. The result of the test systems shows, for practical power systems, that the GWO is a better option to solve the ELDP problems.**

I. INTRODUCTION

Today, as an engineer it is always in concern to obtain a product at a minimum cost by reducing either the product operating cost or by reducing the raw or input cost to the production unit. The electric power demand is growing due to the advances in both industrial and public sector. The major source for this electric power is mainly thermal plants and they are expected to satisfy the load demand. For any thermal plant in general, the generation cost will be proportional to the fuel cost. So, in order to provide lower generation cost, proper load sharing of generating units are required.

Several deterministic optimization approaches were proposed to solve the ELDP, including lambda iteration method, gradient method, linear programming, non-linear programming, dynamic programming and quadratic programming. But these methods require vast efforts in terms of computation. Due to complexities of computing, therefore developing efficient algorithm to find optimal solution viz. genetic algorithm, particle swarm optimization, evolutionary programming, artificial bee colony optimization, and biogeography based optimization; bacterial foraging, Improved Differential Evolution, Tournament-based Harmony Search and Oppositional based Grey Wolf Optimization algorithms and also their variants came into picture This optimization problem deals with allocating loads to power generators of a plant for minimum total fuel cost while meeting the power demand and transmission losses constraints. This is numerous variation of this problem which model the one objective functions and the constraints in many different ways. Moreover, we will demonstrate how the GWO works and how this method can be easily adapted in order to solve this objective optimization problem. Therefore, we will discuss why this method is sufficiently accurate and easy to implement for real-time operation and control of power systems. For the efficiency and validation of this algorithm, we will use, as an example, a sample realistic test system having six power generators. We will also compare the solutions obtained with the ones obtained by alternative optimization techniques that have been successfully applied by many scientists in order to solve these types of problems, such as the goal attainment Genetic algorithm; Particle swarm optimization; Artificial Bee Colony optimization; Biogeography-Based Optimization ; Bacterial Foraging algorithms: Improved Differential Evolution ; Tournament-based Harmony Search and Oppositional based Grey Wolf Optimization algorithms.

The remainder of this paper is organized as follows:

Section II of the paper provides a brief description and mathematical formulation of ELDP. The concept of GWO is discussed in Section III. The original GWO approach is described in Section IV along with a short description of the algorithm used in this test system. The parameter settings for the test system to evaluate the performance of GWO and the simulation studies are discussed are discussed in Section V. The conclusion, some suggestions and ideas for further research are drawn in Section VI.

II. PROBLEM FORMULATION

The ELD may be formulated as a nonlinear constrained problem. The convex ELD problem assumes quadratic cost function along with system power demand and operational limit constraints.

II.1. - ELD with quadratic cost function without transmission loss. The objective function FT of ELD problem may be written as:-

$$F_T = MIN(\sum_{k=1}^{n} F_k\,[P_k]) \quad (1)$$

$$F_T = MIN(\sum_{k=1}^{n} a_k + b_k P_k + c_k P_k^2) \quad (2)$$

$$F_k(P_k) = a_k + b_k P_k + c_k P_k^2 \quad (3)$$

The ELD problem consists in minimizing subject to the following constraints: -

1. *Real Power Balance Constraint:*

$$\sum_{k=1}^{n} P_k - (P_D) = 0 \quad (4)$$

2. *Generator Capacity Constraints:* The power generated by each generator shall be within their lower operating limit and upper operating limit.

So that,

$$P_k^{min} \leq P_k \leq P_k^{max} \quad (5)$$

II.2. - ELD with quadratic cost function with transmission loss. The objective function F_T of ELD problem may be written as:-

$$F_T = MIN(\sum_{k=1}^{n} F_k\,[P_k]) \quad (6)$$

$$F_T = MIN(\sum_{k=1}^{n} a_k + b_k P_k + c_k P_k^2) \quad (7)$$

$$F_k(P_k) = a_k + b_k P_k + c_k P_k^2 \quad (8)$$

The ELD problem consists in minimizing subject to the following constraints: -

1. *Real Power Balance Constraint:*

$$\sum_{k=1}^{n} P_k - (P_D + P_L) = 0 \quad (9)$$

2. *Generator Capacity Constraints:* The power generated by each generator shall be within their lower operating limit and upper operating limit.

So that,

$$P_k^{min} \leq P_k \leq P_k^{max} \quad (10)$$

F_T = the total fuel cost, $/hr.
P_k = the thermal power output of k-th generator, MW.
a_k, b_k , c_k = the cost coefficient of k-th generator.
P_D = total load demand.
P_L = total transmission losses.
P_k^{min} = the thermal power generated lower limit.
P_k^{max} = the thermal power generated upper limit.

III. GREY WOLF OPTIMIZATION

Mirjalli presented the Grey Wolf Optimization (GWO) method [22] that is form on the trapping behaviour of the grey wolves (search agents) in nature. The ranking order follows as alpha (α) beta (β) , omega (ω) , and delta (δ) types of search agents. The grey wolves have different groups for different activities like making a group for staying, hunting the prey etc.

III.1. - Searching for prey: The hunting action initially started with some random initialization of search agents solutions from the search space. After the initialization search agents segregated based on their fitness values and recombine after they finding the prey.

III.2. - Encircling prey: After seeking a prey, search agents surround that prey and the surrounding behaviour can be mathematically represented by Eqn. (11) and Eqn. (12).

$$\vec{E}=\left|\vec{O}.\overrightarrow{X_p}\,(k) - \vec{X}(k)\right| \quad (11)$$

$$\vec{X}(k+1) = \overrightarrow{X_P}\,(k) - \vec{B}.\vec{E} \quad (12)$$

Where, k: the current iteration, $\vec{B}$ and $\vec{O}$: are the coefficient vectors. Here$\vec{B}$: used for sustain the distance between search agents grey wolves and prey. $\vec{O}$ represents disincentive in the hunting trail of the prey. Here, search agents position vector is represented by $\vec{X}$ and position vector of the prey is indicated by $\overrightarrow{Xp}$.

Vectors $\vec{B}$ and $\overrightarrow{O}$ are computed as given in Eqn. (13) and Eqn. (14):

$$\vec{B} = 2 X \vec{1} X \vec{r_1} - 1 \quad (13)$$

$$\vec{O} = 2 X \vec{r}_2 \quad (14)$$

*III.3. – Hunting:*After surrounding the prey, search agents focus on hunting. The hunting is generally guided by α, β and ω types of search agents. Among these, α provides the best candidate solution. Mathematically, hunting behavior of search agents is formulated by (15) - (21).

$$E_\alpha = |(\vec{O_1} * \vec{X_\alpha}(k)) - \vec{X}(k)| \quad (15)$$

$$E_\beta = |(\vec{O_2} * \vec{X_\beta}(k)) - \vec{X}(k)| \quad (16)$$

$$E_\omega = |(\vec{O_3} * \vec{X_\omega}(k)) - \vec{X}(k)| \quad (17)$$

$$\vec{X_1} = \vec{X_\alpha}\text{ (k)} - (\vec{B_1} * \vec{E_\alpha}) \quad (18)$$

$$\vec{X_2} = \vec{X_\beta}\text{ (k)} - (\vec{B_2} * \vec{E_\beta}) \quad (19)$$

$$\vec{X_3} = \vec{X_\omega}\text{ (k)} - (\vec{B_3} * \vec{E_\omega}) \quad (20)$$

$$\vec{X}(k+1) = {(\vec{X_1} + \vec{X_3} + \vec{X_2}}/{3} \quad (21)$$

III.4. - Attacking prey: After completion of hunting, search agents attack the prey. Based on the position of α, β and ω grade search agents, the GWO method allows the search agents, i.e. search agents to update their positions to attack the prey. In order to approach the prey, two parameters $\vec{a}$ and $\vec{A}$ are considered. Here, a decrease linearly from 2 to 0 as the iterations increase and variations of $\vec{A}$ are also decline with$\vec{a}$.

III.4.Implementation of GWO for the ED problem: The implementation steps to ELDP problem by using GWO algorithm are shown below.

Implementation steps of the GWO algorithm in ELDP problem:

Step -1	Initialization
(a)	Read cost coefficients and B coefficients.
(b)	Set power limits of each generator output.
(c)	Set number of search agents and maxiter.
(d)	Read GWO parameters: upper, lower limits of Search space.
Step- 2	Initially the locations of the α, β and ω, Initial fitness values randomly chosen as follows.

```
Alpha_pos=zeros(1,dim);
Alpha_score=inf;
Beta_pos=zeros(1,dim);
Beta_score=inf;
Omega_pos=zeros(1,dim);
Omega_score=inf;
Positions=rand(SearchAgents_no,dim).*(ub-lb)+lb;
```

Step 3	Set the step time t=0
Step 4	Calculate the initial positions of the fitness Function. Set the previous finest position of each Alpha to his presant position.
Step 5	Let t=t+1
Step 6	Select the associate of each alpha and calculate the fitness function for each alpha
Step 7	Revise the chronological best position among the search agents and previous finest position of each alpha.
Step 8	Repeat from Step 6, to obtain best value For objective function upto max. Iteration.

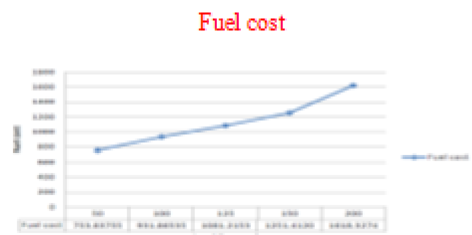

Figure 1 Fuel cost v/s Load Demand curve

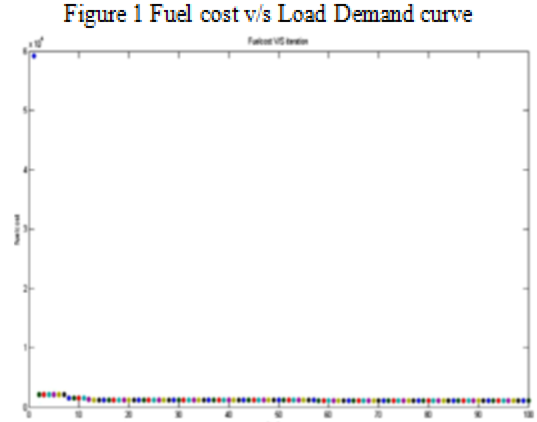

Figure 2 Fuel cost v/s iteration curve 125 MW

IV. THE PROPOSED SOLUTION METHOD

In order to solve the ELDP problem, we have implemented the GWO in Mat lab 2016 and it was run on a computer with an Intel Core2 Duo (1.8GHz) processor, 3GB RAM memory and MS Windows XP as an operating system. Mathematical calculations and comparisons can be done very quickly and effectively with Mat lab and that is the reason that the proposed GWO was implemented in Mat lab 2016 programming environment. In this proposed method, we represent and associate each GLO with a valid power output encoded as a real number for each power generator unit, while the fuel cost objective i.e., the objective function of the problem is associated and represented by population and maximum iteration (termination criteria) are set as 40 and 500. To reduce the statistical errors, test system is repeated 20 times and all simulations are developed in MATLAB 2014a.

The GWO method is essential to meet one power balance equality constraint and 20 powers limits inequality constraints of the system. The optimal generation schedule and selection of fuels among 20 individuals run for cases by the GWO for various Loads.

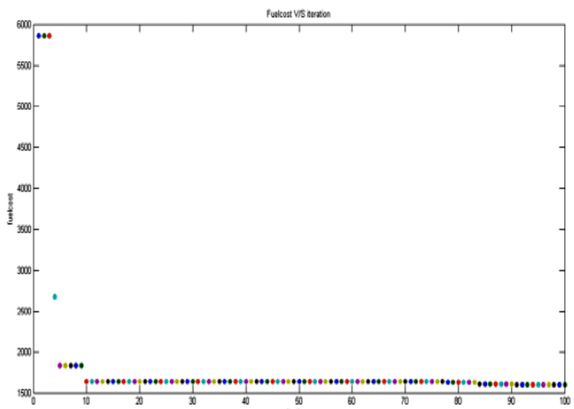

Figure 3 Fuel cost v/s iteration curve 200 MW

V. CONCLUSION

In this paper, GWO method has been proposed and implemented for finding the ELDP with various fuels. While searching for a better solution, GWO does not obligate any statistics about the gradient of the fitness function. The major contribution of the present work was including transmission losses to the test system for various power demands. The outcomes were correlated with other approaches described in the literature and indicated that GWO had faster convergence aspects, improved cost results, dominant computing efficiency and more cognizant accomplishment. The GWO method can be a viable approach to reduce the cost and increases the efficiency for a power grid by providing best power outputs and economic fuel selections. The GWO method is a promising solution for solving complicated non-smooth optimization problems in large scale power system.

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